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DESIGN PARAMETERS OF A PROTOTYPE SYSTEM FOR IMPACT ORDNANCE RANGE CLEARANCE

Conceptual Design and Test Simulation Results

108-TR-2

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SCITEK, INC.

DESIGN PARAMETERS OF A PROTOTYPE SYSTEM FOR IMPACT ORDNANCE RANGE CLEARANCE

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(Conceptual Design and Test Simulation Results)

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SECTION I

A. Introduction

1. Program Objective

Effective methods and mechanized means must be derived for massive decontamination of target ranges, or ordnance impact zones. The objective of this program is to develop design parameters for a prototype hardware system that will perform surface and subsurface ordnance clearance tasks on impact areas. The system would incorporate modifications to existing military and commercial construction and engineering vehicles as well as innovative means for performing the tasks that are necessary for range decontamination.

2. Current Task Objectives

The efforts during this reporting period were predominantly directed toward the conceptual system design and derivation of a representative range model against which the conceptual design could be compared. In addition, the hardware analysis and literature search phases, which were begun in the first reporting period, continued through this period of the program.

During the first week of this reporting period, project investigators visited the Naval Civil Engineering Laboratory, Port Hueneme, and the impact ranges at Twenty-nine Palms and Chocolate Mountain. Since the scheduling of these trips did not permit reporting of the results in the first Interim Technical Report, the two impact ranges are discussed in Annexes A and B of this report.

B. Summary of Range Modeling

1. Topographical Description

The range model can be subjected to a variety of modifying physical descriptors but the first level of generalized description allows three topographic divisions, as shown in Figure 1: flat, generally featureless terrain; undulating, somewhat eroded terrain; and, hills and slopes with complementary cuts, draws, and valleys. First-hand observation and examination of pictorial representations of impact ranges indicates that most of the range areas (certainly, the target zones) are characteristically flat and featureless. This description can be perturbed, in some cases, by impact craters and natural erosion. It is also found, as on the Chocolate Mountain Range, that hills and slopes of 50% or more may occur adjacent to the impact area and, even though the target zones are in the flat region, ordnance contamination will extend onto these slopes.

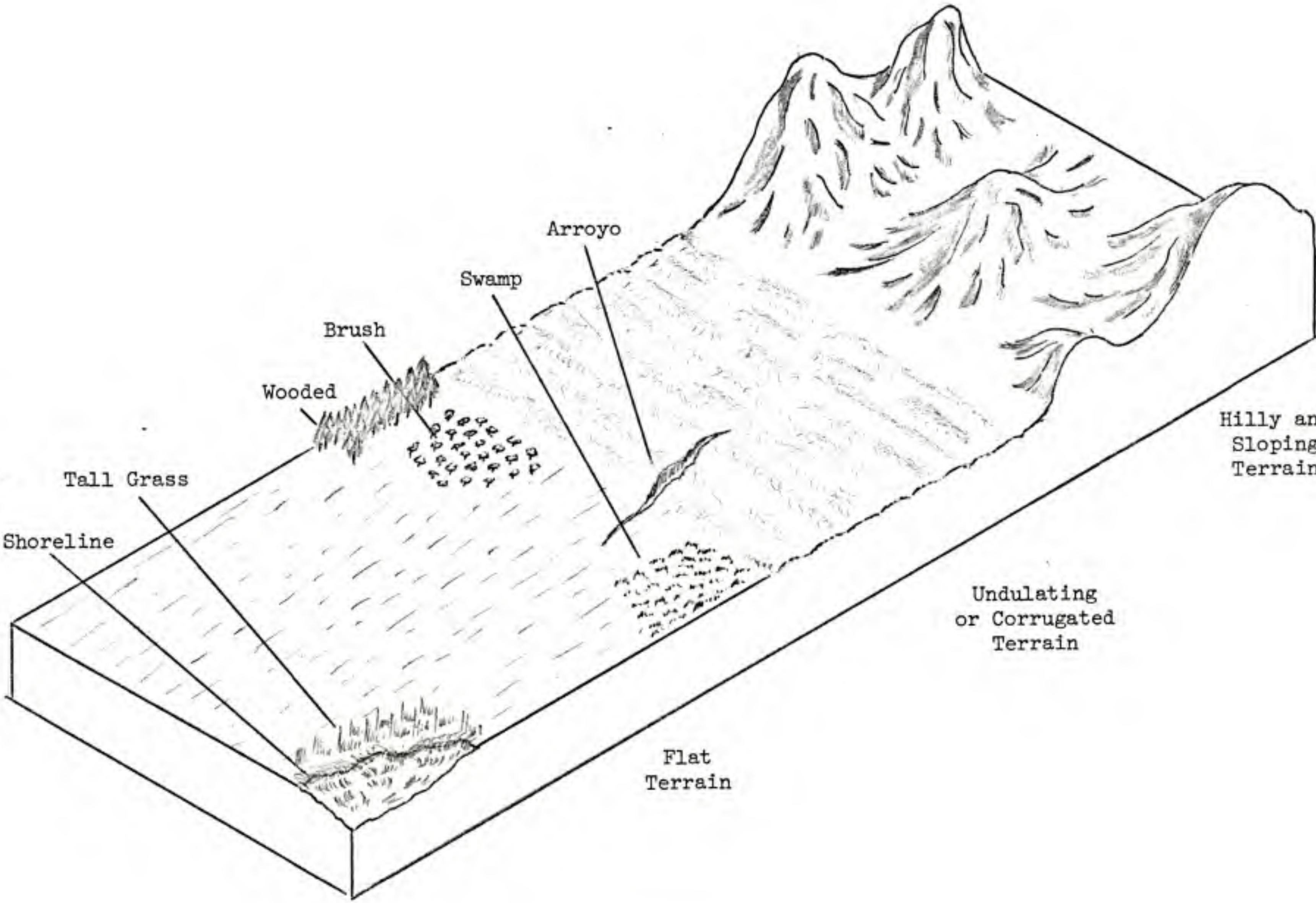


FIGURE 1: Topographical Features on Representative Impact Range.

There are ranges, like Twentynine Palms, which may appear relatively flat from the air, but from ground level present a different view. The surface is generally undulating and scarred by arroyos and other evidence of flash floods, not uncommon in the desert.

The Culebra Range offers an exception, with its hills and sharp drop-offs to the sea. It must be remembered, however, that this range presents these very slopes as targets to the seaward, where ships and approaching aircraft deliver their ordnance into the sides of the hills rather than dropping it onto flat terrain as in the more typical cases. Even this more severe representation of terrain is not prohibitive of mass decontamination. Access is possible to most of the impact range area with vehicles having reasonable rough-terrain trafficability.

The representative range model is grossly illustrated by Figure 1; the modifying features and their influences on the range model are discussed more fully in Section II.

C. Summary of System Concept

1. Essential Clearance Tasks to be Performed

The necessity for removal of ground cover from the impact area will be dictated by the type cover and, of course, the means available for its removal. Some extreme circumstances will exist (e.g., heavy timber) where removal must be deemed impractical. This is stated in exclusion of total burning-off of a forested area, an action rarely justified or condoned. Some ranges will show sparse ground cover as a direct result of range usage; more often, the barren conditions on land traditionally employed for impact ranges tend to alleviate the ground cover problem. There are exceptions. The wooded perimeters and scattered scrub pine on the Pinecastle Range remain a fire hazard during employment of the impact range and would be a problem that must be faced when certain areas of that range must be decontaminated.

Surface debris and ordnance contamination must be given thorough consideration in the clearance system design. It is a prerequisite consideration not only so the equipment needed for subsurface decontamination can be brought into play, but also to facilitate detection of buried ordnance when this technology can be practically included in the clearance operation. It is tempting to envision, under the guise of a "concept," a wonderful machine that moves systematically over the entire range, gathering any and all surface debris and ordnance into its omnivorous craw, making a final and safe disposal of its load at the discretion of an operator. There are in existance, in military and commercial inventories, some vehicles and machines which approach this concept and, with modification, will perform a reasonable vacuum-cleaner function. The idea must be approached cautiously; there will be items of unstable ordnance that may not tolerate the handling that such a machine would give them. There is also the problem of size and weight limitations on the items that can be scooped up and carted away.

The clearance of subsurface ordnance must be considered on the basis of the degree of the contamination present at various depths. There has been no dissuading evidence to change the hypothesis that most of the buried ordnance on an impact range is within three feet of the surface. In fact, the few subsurface contamination efforts on which records exist tend to collaborate this assumption. Reinforced by these reports and valuable first-hand examination of impact ranges, the subsurface clearance tasks in this equipment concept are being approached on the basis of digging at depths of 1 1/2 feet per pass over the area. The number of such passes that would be made would be governed first by whatever information is available concerning the degree of contamination that may be expected. Second, this operation would be reiterative according to the actual subsurface ordnance population that was revealed by each pass of the digging machine.

The search for and recovery of ordnance that penetrates more deeply calls for selective digging and, hopefully, the use of detectors to more assuredly guide these excavations. When this phase of range clearance is required, there are several notable developments in the commercial excavating equipment inventory that deserve consideration. These are described in Section II.

The other nontypical requirement of the range clearance system is the recovery of items of ordnance from steep slopes, ravines, etc. This predicament calls for a machine with long reach, hoist capability, and reasonable maneuverability. The fundamental dragline principle is most promising, providing the machine is small enough to be placed in the most advantageous position for performance of the removal task. The approach to this problem is discussed in Section II.

Culmination of range clearance and decontamination will probably require land reclamation or renovation. The system concept must include a prime mover with dozing capability; whether this is the D-type bulldozer, a medium capability scraper, or a drag-bucket configuration, is subject to final design analysis.

2. Basis for Acquiring Equipment: Military Designed vs. Available Equipment

The two basic means of acquiring earthmoving equipment for a mass range clearance program are: to acquisition military equipment, either available from inventory or through military R&D; or, to consider commercial equipment which is already available [1]. Each of these methods has advantages and disadvantages which must be considered before making a final decision on choosing or fabricating the needed equipment. Since the general military inventory of earthmoving equipment included some commercially available units, the selection methodology for military equipment will be confined to equipment with special characteristics and which came about through a military R&D plan.

Military earthmoving equipment which has evolved from a military R&D program has characteristics not generally available in commercial equipment [2]. One basic reason for this is related to the problem of transporting the equipment. Commercial equipment can be transported by truck or rail and, if the transport time is considerable, the contractor will allow time for this in his work schedule. The military, on the other hand, needs equipment that can be transported easily and quickly; furthermore, this equipment must have the operational capability of heavy equipment.

Another characteristic of military-designed equipment is the job function. Unlike commercial equipment, it usually has a specific task to perform or was intended to perform in a specific environment. The 20-ton Crane, for example, was designed to do general lifting and some digging operations that an equivalent item of commercial machinery could perform; but it must also traverse rough terrain and unimproved roads and still be able to travel unassisted at convoy speeds [3].

The utilization of currently available commercial earthmoving equipment offers many advantages. First, the earthmoving industry spends hundreds of millions of dollars each year in research and development of equipment and in product improvement [1]. The benefits of this are reflected in the equipment; thus assuring the customer procuring the equipment that he is getting the newest and most modern available. Second, through manufacturer testing and customer acceptance, the reliability, durability, capacity, and performance of the equipment is well-established [1]. Today's manufacturer simply cannot afford to sell an unproven machine to the commercial market. Another consideration is that equipment readily available "off-the-shelf" results in a substantially lower item cost. Research and development costs of "off-the shelf" existing commercial machines tend to amortize across the manufacturer's line. This results in a lower cost per machine to each buyer, whereas a machine of new design reflects research and development costs [2]. Rapid response in parts and service support is realized with the use of currently available commercial equipment, although statement of this advantage is made with full realization that it is not always the case.

There is one drawback to the use of commercial equipment. To date, the number of equipment manufacturers and the list of models they offer is staggering. For example, 11 manufacturers offer 63 different models of self-propelled scrapers and 32 manufacturers offer 157 different models of front-end loaders [1]. Not only does this situation develop a problem of training operators, but one of an enormous parts inventory for repair of such diverse vehicles. Of course, not all companies would be represented in the range clearance system, but the differences between two machines from different manufacturers would require a large variety of replacement parts.

Because of the availability, reliability, rapid service, and cost considerations, commercial equipment should be used whenever possible. To further simplify the system, the components should be standardized as much as possible; the main standardized components being the engine, transmission, and torque converter. But a mass clearance program presents some unique earthmoving and sifting tasks which no commercial earthmoving equipment is capable of performing without modification.

It is here that certain items of military equipment may fill the gap. Therefore, a combination of commercial and military designed equipment will be required.

3. The Equipment Family Concept

To develop a family of equipment for a mass range clearance program, one, or a combination, of three methods can be utilized. The equipment for the family can be chosen from: equipment in existence that will need little or no modification; equipment in existence which will require major modification; or, the use of one prime mover with multiple work platforms (or components). Selection of a family of equipment will be based on the following criteria: compatibility with other equipment in the family, easily transportable by C-130 or CH-47, easily operated, and efficient in performing the required tasks [2].

The use of equipment in a family system that requires little modification has one major advantage--initial cost and outlay. Earthmoving equipment chosen for such a system concept would most liekly be of the "off-the-shelf" variety. The cost of such equipment, for previously mentioned reasons, would include a low R&D cost as compared with military-designed equipment. Modifications that would be performed to such equipment would be the addition of extra lights, assurance of safety to the operator, and painting it in military colors.

Since there is little cost involved in these types of modifications, the main consideration in this approach would be the acquisition cost of the equipment itself.

4. Remote Control Considerations

A major reason for introducing equipment into a massive range clearance program is to provide greater safety to the personnel involved [10]. Although the use of equipment will afford greater protection to its operator, he still must be on the range operating the machine during clearance operations. One method to provide greater safety is through the use of remote control of the equipment.

Remote control not only affords greater safety by removing the operator from the actual clearance operations, but also by providing an improved operating environment [11]. By having the operator away from the machine, he is free from the shock, vibration, heat and noise, and thus more relaxed and less fatigued over the period of operations than he would be if he were aboard the machine.

Improved operating efficiency also results from the use of remote control [11]. By being in a free position in relationship to the operating machine, the operator can actually see its relative position in relationship to the topography. On-board operation requires an expert intuition of "feel" at best which comes only with experience and skill. Since remote control would enable the operator to actually see the work being performed instead of relying on intuition, productivity can be increased.

SECTION II

A. Model of a Representative Range

1. Basis for the Model

As discussed in Section I and illustrated by Figure 1, the range model can be assigned three gross topographical divisions. The flat terrain more closely resembles the majority of existing impact ranges. The undulating surface is representative of some ranges, or portions of some, which present slightly more rugged features. The hilly or mountainous portion would be like that found on a few impact areas but more often is a peripheral topographic feature and presents a special case. To be more realistic in constructing a model that includes the diverse features necessary for evaluation of a system concept, there are appropriate factors (or features) that must be superimposed on the model.

2. Surface Characteristics

The following characteristics are presented in outline form and will be combined in various ways during the simulation of the system concept operation on the range model.

a. Ground Cover

1) Forest

a) Evergreen

b) Deciduous

c) Combination

2) Scrub

a) Dense

b) Scattered

3) Grass

a) Tall

b) Short

4) Rock

a) Shelves; Outcroppings

b) Boulders

c) Dense, loose stones

d) Strewn stones

5) Barren

b. Topography

1) Mountains; Hills

a) Slopes, 20% to 100%

b) Geologically, old (e.g., Appalacian)

c) Geologically new (e.g., Rockies)

d) Volcanic origin

e) Folded; lifted

2) Valleys/Canyons

3) Plains/Plateaus

a) Flat

b) Gentle undulation

c) Corrugated

4) Other Features

a) Surface Water

- Shoreline
- Rivers/Streams
- Lakes

b) Faults/Gorges

c) Man-made

- Buildings
- Bridges
- Roads
- Target Structures/Vehicles

3. Subsurface Characteristics

a, Soil (strata description)

b, Water Table

c. Buried Debris, Man-made (non-ordnance)

d. Rock

4. Ordnance Contamination

   a. Surface

      1) Large Bombs/Missiles/Rockets

      2) Medium Bombs/Missiles/Rockets and Large Artillery/Gun Projectiles

      3) Small Bombs/Missiles/Rockets and Medium Artillery/Gun Projectiles

      4) Submunitions/Bomblets and Small Artillery/Gun Projectiles

      5) Miscellaneous Ordnance (flares, small arms ammunition)

      6) Debris

         a) Shrapnel

         b) Fins and other dispersed components

         c) Target Scrap

   b. Subsurface, to 1 1/2 feet

      1) Large Bombs/Missiles/Rockets

      2) Medium Bombs/Missiles/Rockets and Large Artillery/Gun Projectiles

      3) Small Bombs/Missiles/Rockets and Medium Artillery/Gun Projectiles

      4) Debris

         a) Shrapnel

         b) Fins and other dispersed components

         c) Target Scrap

c. Subsurface, 1 1/2 to 3 feet

1) Large Bombs/Missiles/Rockets

2) Medium Bombs/Missiles/Rockets and Large Artillery/Gun Projectiles

3) Small Bombs/Missiles/Rockets and Medium Artillery/Gun Projectiles

d. Subsurface, 3 to 6 feet

1) Large Bombs/Missiles/Rockets

2) Medium Bombs/Missiles/Rockets and Large Artillery/Gun Projectiles

e. Subsurface, 6 to 15 feet

1) Large Bombs/Missiles/Rockets

f. Subsurface, 15 to 25 feet

1) Large Bombs/Missiles

g. Subsurface, over 25 feet

1) Large Bombs

5. Meteorological Conditions

a. Seasonal

1) Cold-dry

2) Cold-wet

3) Hot-dry

4) Hot-wet

b. Precipitation

1) Rain

2) Snow

3) Fog

c. Extremes

1) Flooding/Tidal

2) Drought

3) Windstorm/Duststorm

4) Snowstorm

B. <u>Design Concept for a Range Clearance System</u>

1. Functional Requirements

The conceptual design is based upon the necessity of performing a set of tasks on the representative range which has been modeled. These tasks are:

a. Surface cleanup

b. Shallow subsurface clearance

c. Moderate subsurface clearance

d. Deep subsurface clearance (selective basis only)

e. Ordnance recovery in rugged terrain

f. Land renovation

With regard to performance of each of these tasks, the concept design must exhibit operational capabilities that meet the goals of a range clearance system. Special consideration must be given to: transportability, trafficability, ruggedness, and survivability.

2. Surface Cleanup

A preliminary survey of the area to be cleared must be conducted by EOD personnel. This survey would identify critical problems in the surface contamination that may affect the operation of equipment over the surface area. Sensitive fuzes, unstable ordnance items, and ordnance or debris too large for handling by the surface cleanup machine, may have to be disposed of by other means and before the mechanized surface clearance begins.

The sketch in Figure 2 illustrates how the surface contamination problem may be approached. The lead vehicle would serve as the prime mover and tow a digging machine for the shallow subsurface function. The collection of surface debris would have to be done at a width at least equal to the track width of the vehicles. The tow bar between vehicles would incorporate an automatic release so that the hitch would release when the towed vehicle blade encountered a subsurface object beyond its digging or handling capability. In the final analysis of the system design, it may be found that the functions of the two vehicles shown in Figure 2 can be accomplished by one machine.

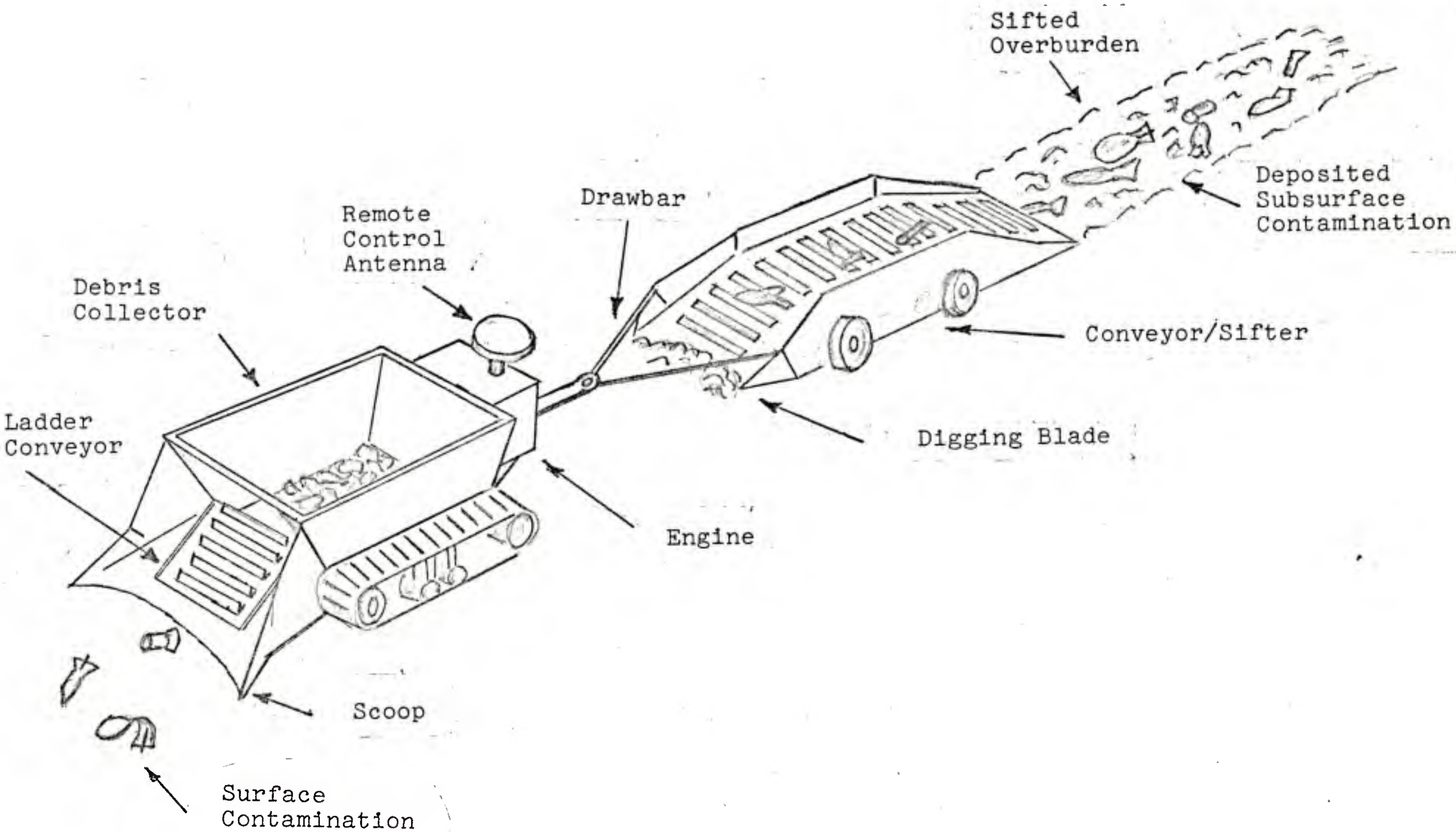


FIGURE 2: Surface and Shallow Subsurface Clearance Concept.

The Universal Engineer Tractor (UET), shown in Figure 3, is one military vehicle that could be considered for the prime mover role in this concept. It has a number of unique features. This is a "ballastable" vehicle whose empty weight of 32,000 pounds permits it to be transported by C-130 aircraft. Once at the work site, the vehicle uses its "self-loading" capability by employing its scraper blade to take on the required ballast. Other construction capabilities include dozing, amphibious operation, and hauling.

The suspension of this vehicle is a feature of major interest [5]. The hydropneumatic suspension system allows ground clearance from 8 to 15 inches, which can be predetermined. To accomplish this, there are eight nearly identical suspension systems consisting of: a road arm, a rotary actuator, an accumulator, a leveling valve, and a wheel valve. When an irregularity is encountered, the road arm moves to activate vanes in the actuator. This, in turn, forces oil into the accumulator which acts as a spring when the oil compresses the nitrogen gas. The leveling valves automatically maintain the predetermined ground clearance by supplying oil to the proper side of the rotary actuator vanes.

When performing earthmoving functions, rigid suspension with wheel positioning is provided by throwing a control

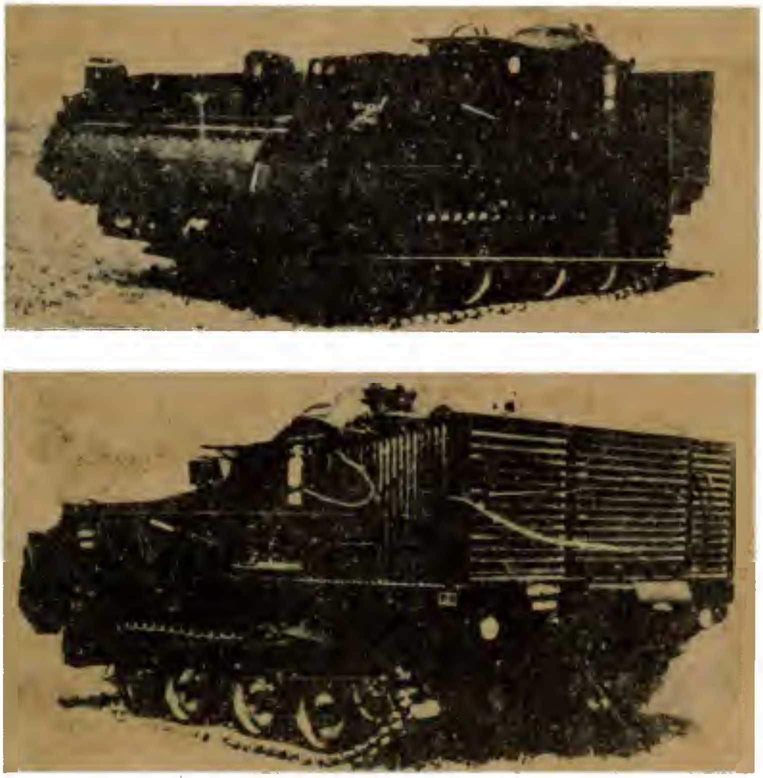


FIGURE 3: Front and Rear View of Universal Engineering Tractor (UET).

FIGURE 4: UET, Ballasted, Performing Dozing Operations.

valve in the driver's compartment. By actuating a set of levers, either or both front corners of the machine can be raised or lowered. The performance characteristics for the UET are shown in Table 1.

TABLE 1: PERFORMANCE CHARACTERISTICS OF UET

Weight	
Net :	32,000 lb
Airdrop :	32,000 lb
Gross :	57,200 lb
Payload :	24,000 lb
Engine H.P., Net:	265 @ 2,800 rpm
Suspension :	hydopneumatic
Fuel Capacity :	130 gal
Ground Pressure	
Empty :	8.2 psi
Ballasted :	14.1 psi
Performance	
Maximum Speed	
Land :	30 mph
Water :	3 mph
Gradeability :	60%
Cruising Range:	200 miles

One measure of worth for the UET is to consider that it performs the multiple functions of units that would require 12,000 spare parts, whereas only 2500 reserve parts are required for the UET.

Another machine with features relevant to the surface cleanup required is the "Super Rock Eater," manufactured by Alpine as an underground mining machine. As shown in Figure 5, this vehicle already has the capability of gathering material into an open-throat scoop and then depositing the material toward the rear by means of an integral conveyor system. The digging arm would not lend itself to excavating ordnance so it is the lower half of this machine that is germane to the requirements addressed by this investigation. In its intended role of mining coal, the rotating tines or picks on the digging arm loosen the undisturbed soil either above, at the same level, or below the machine's tracks. The loose material is then gathered up by arms rotating on the inclined surface (scoop) and deposited on the conveyor belt, which then dumps the material into a waiting hopper. The parallels with the surface ordnance cleanup requirement are close enough to warrant closer study of this machine.

3. Subsurface, Shallow and Moderate

The towed vehicle in the sketch, Figure 2, is tasked with digging into the soil and extracting buried ordnance or debris about 1 1/2 feet below the surface. The drawing is based on a potato digger design and it is intended to show here that the ordnance would be handled very much the same as potatos are harvested by this machine. In the fundamental operation shown by the sketch, the ordnance would be dug up

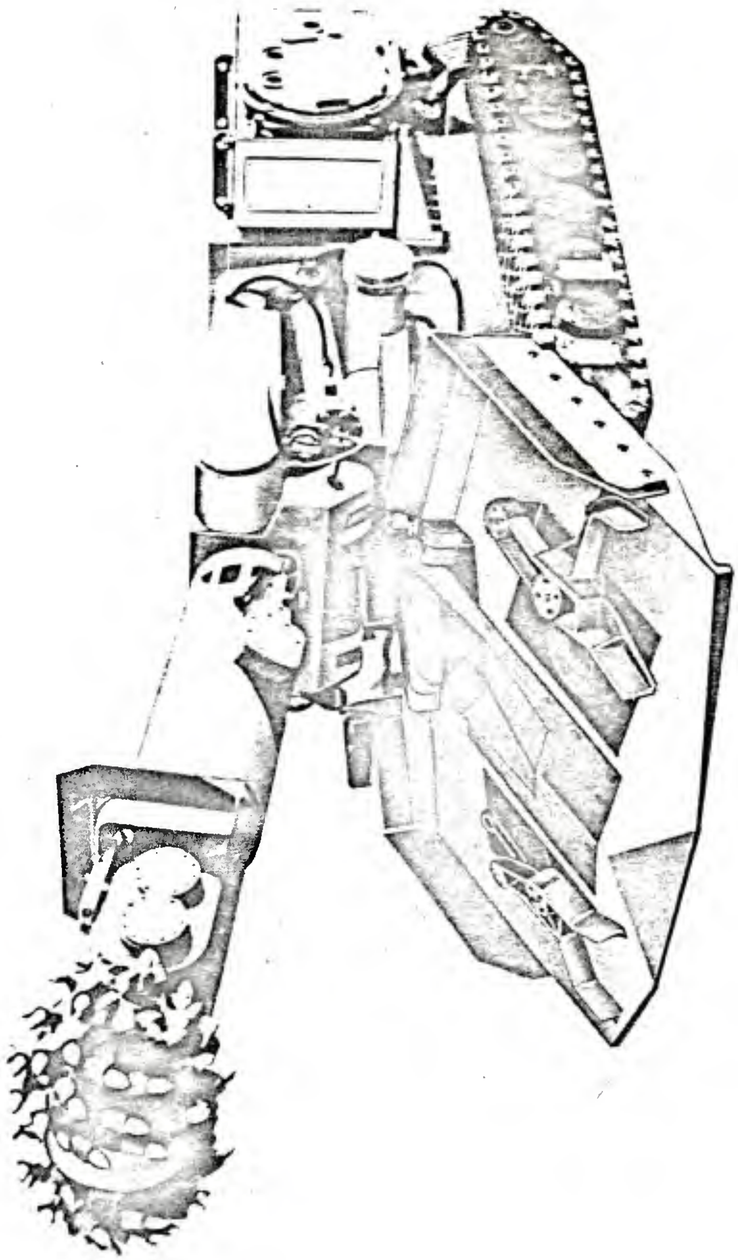


FIGURE 5: The ALPINE AM-50 Super Rock Eater

by the blade, moved on to a conveyor, and then deposited from the rear and on top of the soil that has been plowed. This ordnance can then be collected by the surface cleanup vehicle on a later pass through the area. It is more desireable, also more complex, to provide this machine with a sorting capability; i.e., ordnance (metallic) material would be collected into a bin and other material, such as stones, would be discarded.

4. Subsurface, Deep

Recovery of ordnance at depths greater than three feet must be regarded as the most difficult aspect of range clearance. Wholesale excavation of the range area is bound to be prohibitively expensive and time consuming. There are undoubtedly some ranges where deep recovery is necessary, but this operation must be initiated after evidence is indicative of success and it is deemed necessary to go to these depths, as decreed by the decontamination requirements.

Within the military inventory, one of the more versatile vehicles that can be applied to the deep subsurface task is the 12 1/2 Ton Crane, Model 22-BM [8,9]. This vehicle (Figure 6) is powered by a diesel engine and is fully crawler mounted. By attaching various booms, it can be utilized as a dragline, crane, shovel, clamshell, backhoe, or pile driver.

FIGURE 6: Full-Tracked, DED, 12 1/2 Ton Crane

The 30-foot boom length can be increased with additional sections. Because of its low speed (1.5 mph), use of the crane would be limited to excavation from hills or performance in a centralized location where a particular clearance problem demands such a machine. Because of this low speed, the crane would have to be truck-transported. The specifications for the 12 1/2 Ton Crane appear in Table 2.

TABLE 2: 12 1/2 TON CRANE SPECIFICATIONS

Weight : 51,000 lb	Performance
Engine	Maximum Speed : 1.5 mph
Displacement : 401 Cu in	Maximum Grade : 31 %
Net Horsepower: 75 @ 1635 rpm	Fuel Consumption: 1.07 gph
Fuel Capacity : 50 gallons	
Auxiliary Equipment	
Shovel Front	Clamshell Components
Backhoe Front	Piledriver Front
Dragline Components	

The Liebherr 901 Series Backhoe, Figure 7, can be directly applied to the selective excavation requirements that occasionally arise. Of special interest is the ability for rotation of the clamshell or orange peel grappels [6]. This ability permits selective digging of a restrictive area, without entrenching, simply by rotating the clamshell during the digging operation. There are a number of different bucket attachments which permit performance of variable tasks. (See Figures 8 and 9.) Mounted on low pressure tracks, the undercarriage is sealed and requires no maintenance.

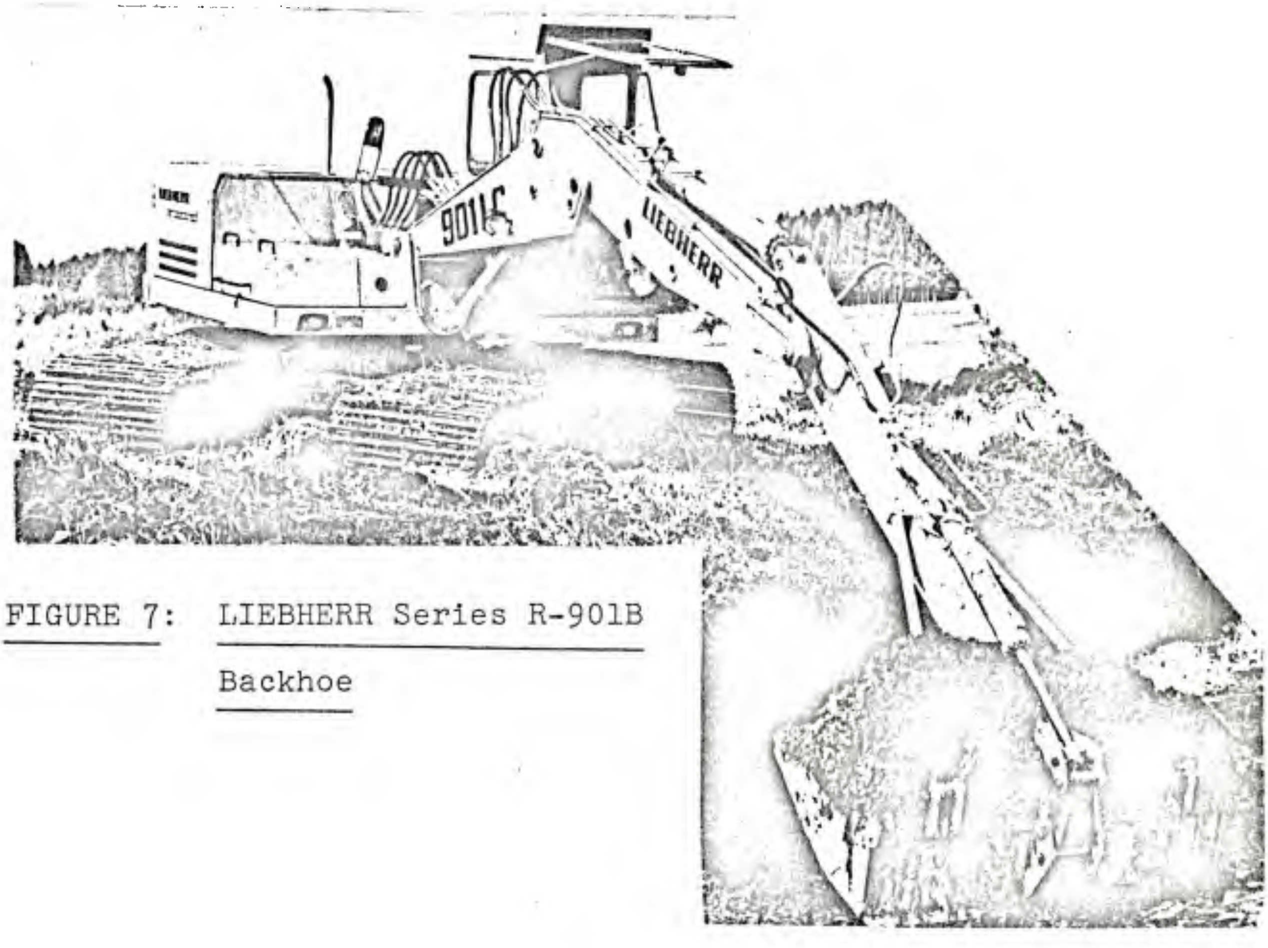


FIGURE 7: LIEBHERR Series R-901B Backhoe

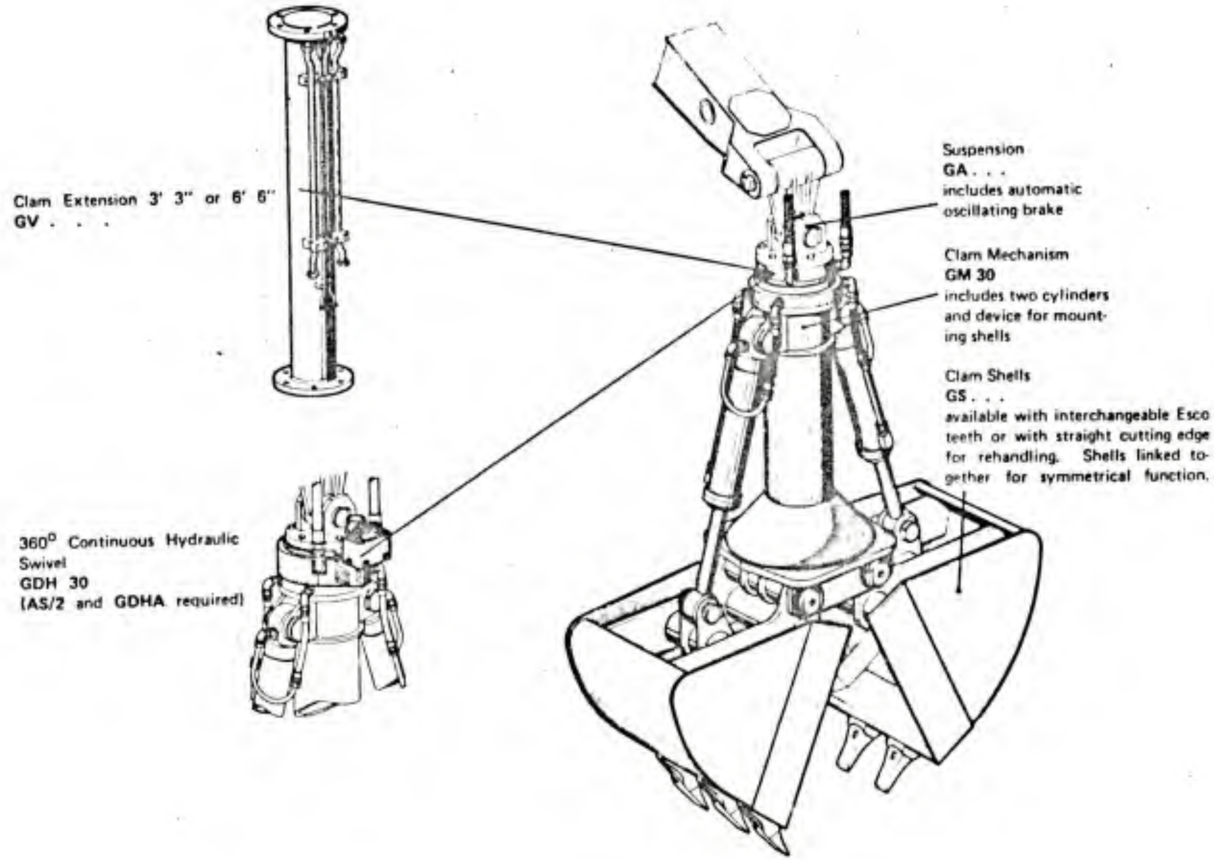


FIGURE 8: Rotating Clam Bucket for the LIEBHERR R-901B Series Backhoe

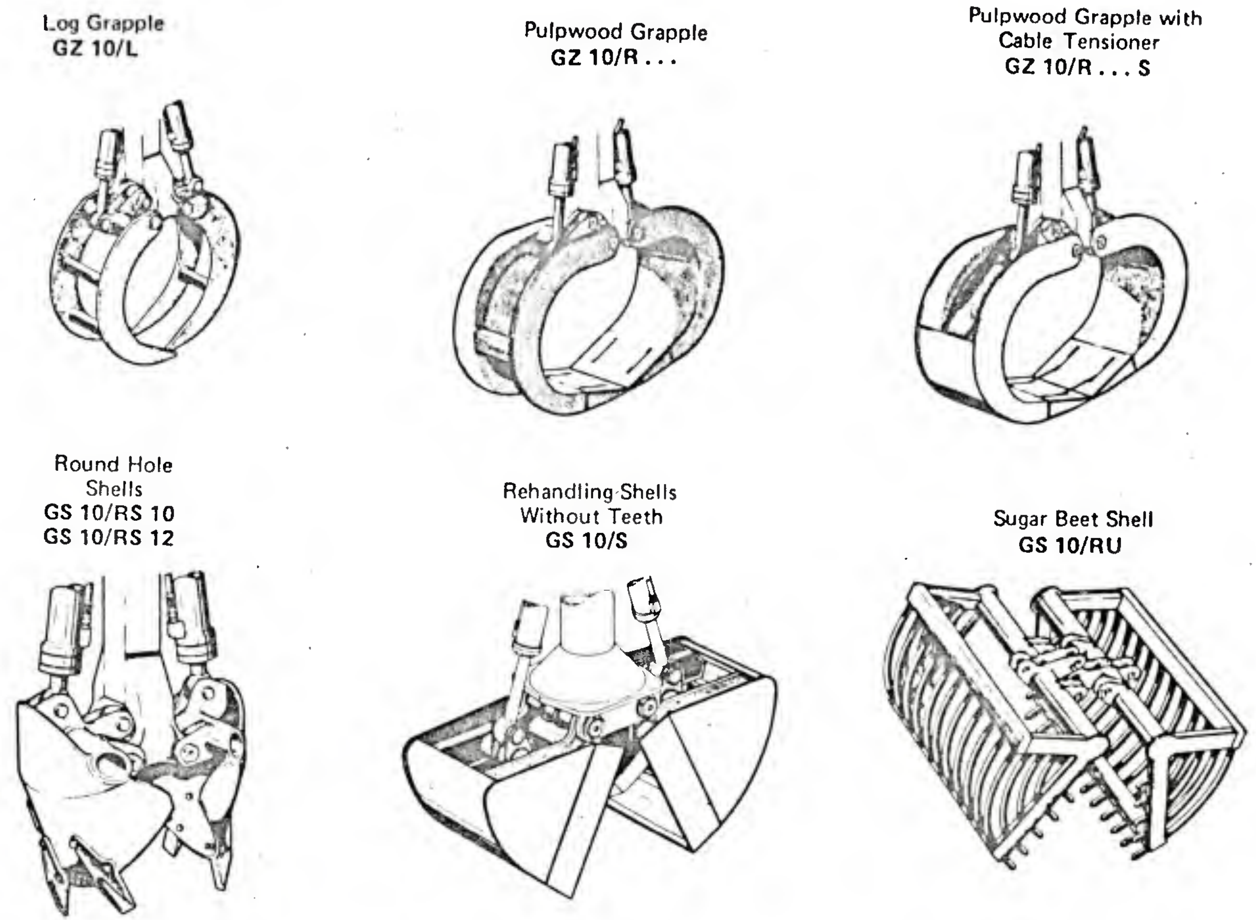


FIGURE 9: Different Buckets Available for the Series R-901B LIEBHERR Backhoe

5. Additional Equipment Considerations

In order to airlift the equipment easily without performing major modifications, careful consideration must be given to the choice of equipment. Of major concern are the weight limitations imposed by the aircraft. This narrows the candidates considerably. For example, a Caterpillar Model 966, which weighs approximately 30,000 pounds (see Table 3), could not be airlifted by a CH-47C (which has a payload of approximately 23,000 pounds) [2,4] . Tractors requiring little modification that meet the weight limits are the John Deere JD-600 and the MRS I-801 (Table 3). When considering equipment light enough to be air transported without modification, a trade-off must be realized in the performance of the equipment. Because of the lighter weight, drawbar pull will be a limiting factor in the choice of dozer blade or bucket loader size. It would be useless to supply a loader, for example, with a 4 cubic yard bucket if the machine cannot develop the tractive effort or power to fully utilize that bucket.

Careful consideration must be given to assure compatibility of selected trucks with the loader that is chosen. The largest loader that can be chosen is the Caterpillar Model 950 with a 2-1/2 cubic yard bucket [2].

TABLE 3: Performance Parameters of Available Military Dozers and Loaders.

	Horsepower (flywheel)	Efficiency (%)	Vehicle Weight (x 1000 lbs.)	Number of Drive Wheels	Percent of wt. on Drive Wheel (%)	Tire Contact Area (ft^2)	Width of Blade ft	Height of Blade ft	Max Speed (ft/mi)	Bucket Heaped Vol. (ft^3)	Lift Capacity (x 1000 lbs.)	Cycle Time (min)
JD-600	101	70	11.0	2	75	1.62	7.50	2.0	1530	--	--	--
MRS I-80T	141	70	17.5	4	100	2.43	8.00	2.5	2480	--	--	--
Cat. 966	150	70	30.0	4	100	1.62	8.84	3.5	2540	87.6	18.9	0.40
Trojan 3000	172	70	30.0	4	100	1.62	8.84	3.5	2060	94.5	19.1	0.40
Euclid 72-41	151	70	30.0	4	100	1.64	8.84	3.5	2360	87.6	19.4	0.40
Hough H-900	165	70	29.0	4	100	1.84	8.84	3.5	1900	81.0	9.0	0.40
FAMECE	250	70	30.0	4	100	1.84	8.84	3.5	3080	67.5	19.0	0.40

The ideal situation, depending on the number of trucks and the length of the haul, is for a truck to have a capacity three to five times that of the loader's bucket capacity. Although there is only one truck, the WABCO "D", shown in Table 4 that meets the weight requirements, there are several on the commercial market with various capacities that meet that requirement. If the truck chosen is too large or too small. efficiency of the system will be greatly reduced.

Equipment can be modified to meet weight and size requirements in a number of ways. A Caterpillar Model 966, for example, in order to meet width requirements could have its 20.5-25 tires replaced by 18.00-25 tires [2]. Also a tractor of this size exceeds the requirements for airlift so the counterweights would have to be removed.

Although time would be needed to assemble this equipment once it arrived at the work site, overall production would be increased due to the higher production rates that can be achieved by the heavier equipment. This results from the greater rimpull and drawbar capabilities. The Caterpillar Model 966 (Table 3), with its heavier weight and more tongue, is capable of being fitted with a larger blade than a JD-600, which conforms to all physical and weight standards without modification [2].

Also because of the power capabilities of the tractor and through the use of modifications, the dozer can be utilized

TABLE 4: Performance Parameters on Available Military Dump Trucks.

	Horsepower (Flywheel)	Efficiency (%)	Weight (x 1000 lbs.)	Haul Capacity (x 1000 lbs.)	Heaped Payload (ft^3)	Speed (ft/min)	Number of Drive Wheels	Tire Contact Area (ft^2)	Percent of wt. on Drive Wheels (%)
A.C. TR 160	155	80	28.10	24.00	324	2240	2	1.69	59
Wabco "D"	134	80	22.54	22.00	284	2300	2	1.62	50
Euclid 5-7	135	80	29.00	24.00	324	2250	2	1.62	55
Hough E-200	135	80	29.00	24.00	324	2210	2	1.62	50
FAMECE	250	80	29.00	24.00	324	3080	4	1.84	61

as a loader (Table 3). Through the use of a multipurpose bucket, the same prime mover can load, doze, or pick up objects such as stumps by use of clam action.

The setbacks in such a system are cost and teardown or assembly time. Although, considering the greater performance, these factors could be justified.

6. The Family System Concept

The system concept of utilizing one prime mover with multiple attachments is in the development and preproduction stages. Clark Equipment Company, Construction Machinery Division, has been awarded a contract by the U.S. Army for development of FAMECE (Family of Engineering and Construction Equipment). Figure 10 shows the scraper module of this system with the prime mover attached. An approach such as displayed by the FAMECE system offers many abilities. First, development of the system was centered around the ease of transportability to front line units [2]. In doing so, each module is within the physical constraints and no module alone weighs over 15,000 pounds. This allows airlift, without modification, by either C-130 or CH-47C. Disassembly or reassembly of any components and the prime mover requires no more than 30 minutes, thus increasing the working efficiency of the system.

By using one power module to do all the dozing, loading, scraping, hauling, spreading and compaction, the operators have only one basic layout of controls with which to become familiar. Thus the operator quickly acquires ability and confidence, with resulting increased system efficiency and productivity.

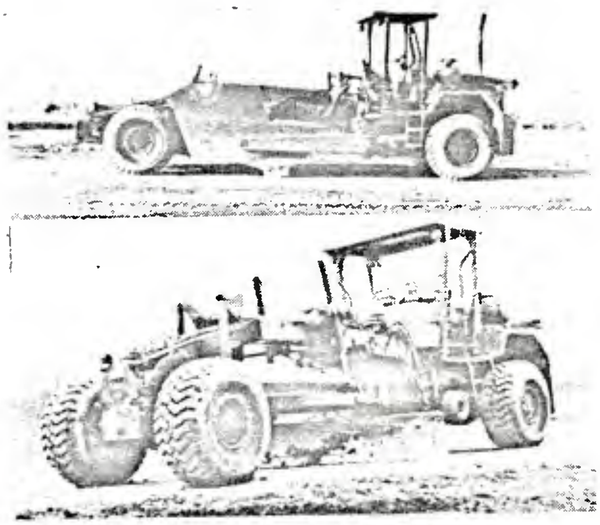


FIGURE 10: FAMECE Scraper and Grader Being Developed by Clark Equipment Company, Construction Machinery Division

Another goal of the design of the FAMECE was to have a military system capable of performing better than equipment of equal size. In a study conducted by TRW Systems Group, Washington, D.C., the FAMECE was found superior in performance to commercial vehicles except for loading, in which a Trojan 3000 had a higher productivity rate, and dozing, in which all modified tractors and the FAMECE shared the honors. These comparisons are shown in Table 5.

TABLE 5: Equipment Having the Highest Productivity During Computer Investigation of Different Family Concepts.

Work Function	Highest Average Productivity All Tasks	Highest Productivity Single Task
Dozer Cleaning	FAMECE	All modified and FAMECE
Dozer Stripping	FAMECE	FAMECE
Dozer Earthmoving	FAMECE	FAMECE
Dozer Supporting Loaders	FAMECE	FAMECE
Bucket Loader	Trojan 3000	Trojan 3000
Scraper	FAMECE	FAMECE
Grader, Road Maintenance	FAMECE	FAMECE
Grader, Leveling Fill	FAMECE	FAMECE
Dump Truck	FAMECE	FAMECE
Water Distributor	FAMECE	FAMECE
Compactor	FAMECE	FAMECE

One other advantage is that of maintainability. Since only one prime mover is being utilized, the stock of spare parts need not be as great as the use of multiple prime movers. The same holds true in the service of the vehicle.

The family system concept designed for a mass range clearance program should be constructed around two basic parameters, cost and ease of air-transportability. A deciding factor would be the performance ability of the evolved systems. Commercially available equipment which requires little modification has a low cost compared to the other candidates for the system concept. Also, because of its size, it can be easily transported with no time lag for disassembly or reassembly of the system. But, because these factors limit the size of the equipment chosen for such a system, the performance output is the lowest of the three concepts [2].

In choosing equipment of a larger size, the initial purchasing cost is roughly only a small amount more than the smaller equipment. But, because of the modifications needed to be able to airtransport, the cost raises a little more. Coupled with the time to disassemble and reassemble, any cost advantages are lost in time and modification. The advantage of this concept is that the larger machines have a higher performance rate than the smaller unmodified equipment.

The FAMECE type equipment of military design has the advantages of being easily air-transported, easily operated, and easily maintained. Since this military concept was designed around ease of transporting, no modifications need be performed. Also, assembly and disassembly between any module and the prime mover requires no more than 30 minutes. The system is easily operated because of the use of only one prime mover; and, since only one prime mover is utilized, the supply of parts need not be enormous. Performance of the system is superior to the two previously mentioned commercial concepts except for loading operations. Replacement of the standard 2-1/2 cu. yd. bucket with a 3-1/2 or 4 cu. yd. bucket would increase productivity. One disadvantage is the cost of the system. Because of the research and development needed to design and test the concept, the cost is going to be greater.

The FAMECE is a system specially designed to provide easy transporting, short assembly/disassembly time, and performance equal or superior to its commercial counterparts. Operation of the FAMECE in a range clearance system might include providing the prime mover for the clearance operations, hauling and restoration of the land after clearance operations are completed.

7. Special Features

Several techniques are being considered for sorting ordnance from other debris during the surface and the shallow subsurface tasks. The first separation can take place according to object size. When the material is scooped or dug up, a grating or lattice configuration would be incorporated at the beginning of the materials-handling cycle. This would allow loose earth, sand, and small rocks to drop through and back to the ground. The next step is to separate metallic from non-metallic. If the gathered material is moved on a conveyor (as shown in the sketch in Figure 2), a magnetic pulley could be incorporated at the end of the conveyor; non-magnetic material would thus be desposited on the ground behind the machine and magnetic material would remain on the belt through a 180° turn of the pulley and be released on the underside of the conveyor system, into a storage bin. Since some ordnance items are not ferrous, this technique would not accomplish their separation from other debris. If an induction detector would be used, rather than magnetic separation, a wider class of ordnance could be separated just on the basis of being metallic.

8. Remote Control Design

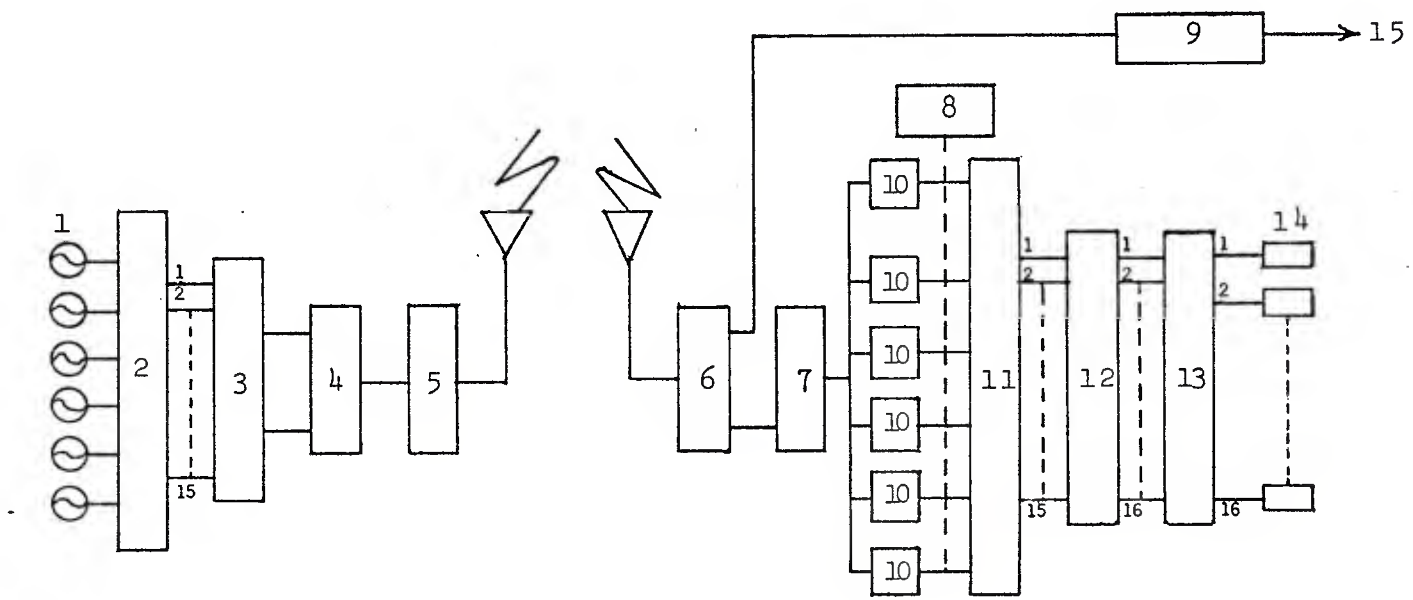
A remote control unit must be able to control three basic functions independently. Each function--movement of the machine, earthmoving operations, and engine control--has many associated commands, which are listed on Table 6 [11]. Since it would be an advantage to control vehicle movement and earthmoving operations simultaneously, the commands are separated into two groups. Once separated, the signals for the chosen commands can be alternately sent in short-time fast repetition.

One method of developing command signals is through the use of signal generators. [11] To obtain the 15 different command signals required on Table 6, six (6) low frequency signals are generated as shown in Figure 11 [11]. These 6 frequencies can then be combined in pairs to create the 15 different signals required.

Choice of the desired commands is made at the control panel (Figure 12) which consists of two four-way operating levers. One lever controls the vehicle movement, the other controls the earthmoving operations. Movement of either lever will close the switch allowing the signal for that command to be transmitted. Change in the position of the operating lever will result in a change of command. Also

TABLE 6: Typical Commands for Operation of a Remote Controlled Earthmoving Machine.

Command Related to Movement
1. Neutral
2. Forward
3. Forward right turn
4. Forward left turn
5. Reverse
6. Reverse right turn
7. Reverse left turn
Commands Related to Earthmoving Operations
1. Shovel hold
2. Shovel raising
3. Shovel lowering
4. Shovel tilting
5. Shovel dumping
Commands Related to Engine
1. Engine starting
2. Engine acceleration
3. Engine deceleration



1 - Basic Oscillator
2 - Mixer
3 - Operation Switch
4 - Electronic Switch
5 - FM Transmitter

6 - FM Receiver
7 - Detection
8 - Self Check
9 - Receiving Wave Check
10 - Band Filter

11 - Matrix
12 - Switching Logic
13 - Power Switch
14 - Pneumatic electro-Magnetic Valve
15 - Engine

<u>FIGURE 10:</u> <u>Control Circuit for a Typical Remote Control Unit.</u>

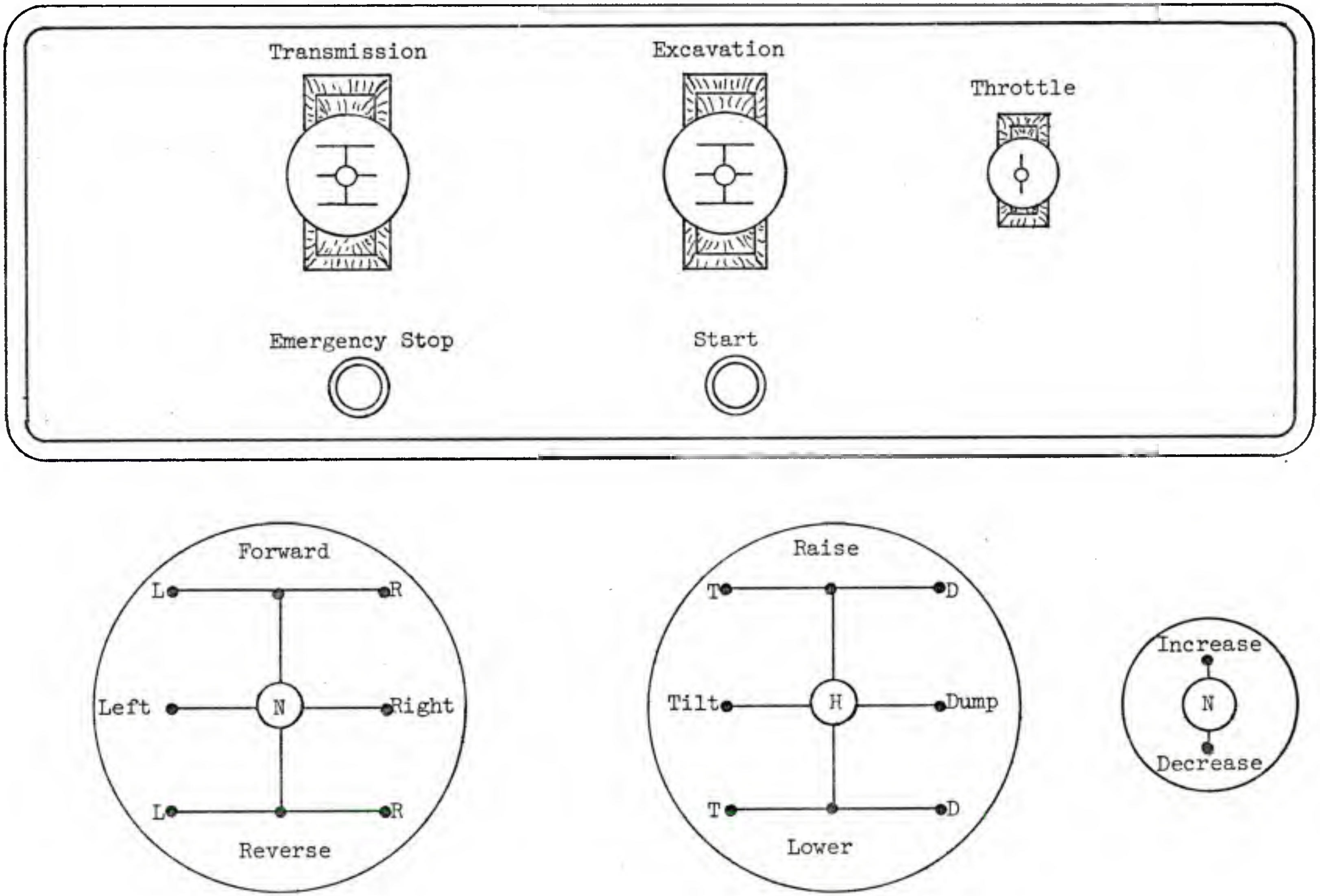


FIGURE 12 : Layout of a Possible Control Panel for a Remote Control System.

on the panel is a lever to increase speed, decrease speed, start or stop the engine of the machine being operated. Two related operations of the same lever cannot be performed at the same time; attempt to do so would automatically stop the machine.

There are many ways of transmitting the signal to the machine. One means is through physical links [12]. One of two methods may be employed: the use of signal or telephone wire, or the use of high frequency signals along high tension power lines. Physical methods such as these would be disadvantaged because of the distance involved. Problems with losses or weakening along such a distance, or the breaking of lines, makes FM (frequency modulation) transmission much more practical [12]. The FM transmitting frequencies for remote control range from 100 to 150 megacycles [11].

Once the signal is received through the FM receiver (Figure 11), a series of transmission checks are made. If no signal is received, or if an improper signal is received, the engine is automatically shut off. The signal is then passed through a detector which separates the FM frequency from the low command frequencies, which is passed on. Each low frequency received is then filtered by one of the six band filters (Figure 11) in order to determine its approximate frequency. After filtering, the frequencies are checked to ensure only two of the six possible frequencies was transmitted. If more than two were transmitted for any reason, the safety check (Figure 11) would stop the machine and shut down the engine.

Once the two frequencies are recognized, they are combined in a matrix to determine the specific command. The resulting signal then operates the proper valve, which can be electrical-oil (hydraulic), electro-pneumatic, or solenoid.

An electric-oil system employs an electronic valve which opens or closes to control the fluid passage. This system is reliable but does present problems in maintenance cost. Also the system is complex in that it is a closed system and return lines would be required [11].

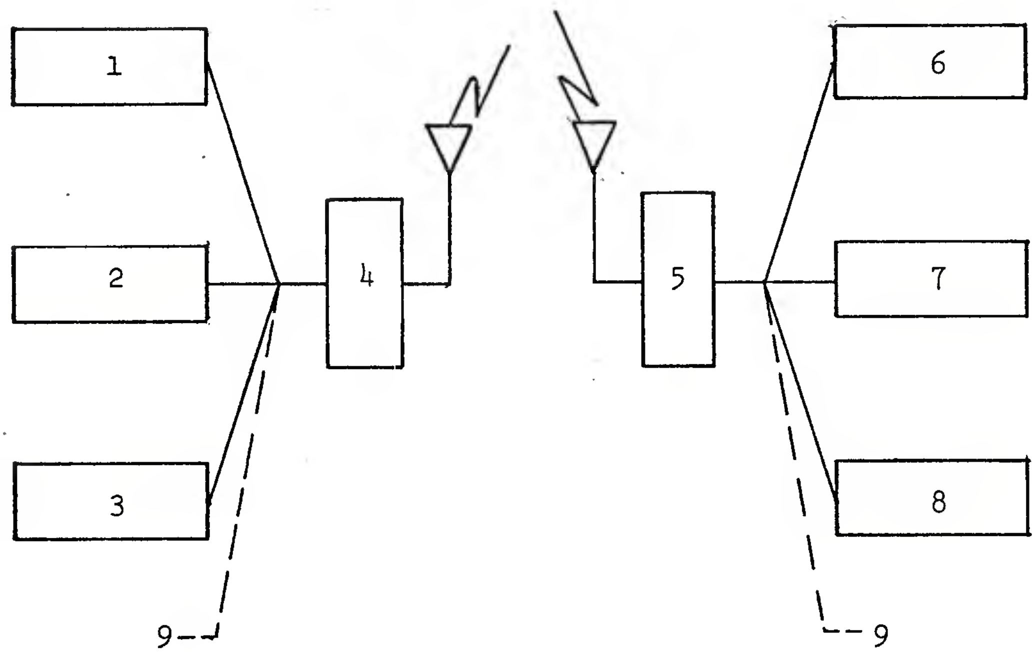
Electropneumatic systems employ a valve which allows an increase or decrease of pressure in the lines [11]. This system has advantages of needing no return line and using small, inexpensive and easy-to-replace parts. A problem of the system is that an air compressor and air tank are required to be on board the tractor. One other problem to be encountered is the air moisture content and the attendant susceptibility of a line freezing closed.

Solenoid systems operate the controls through an on-off system. Advantages of this system are small and efficiency is poor due to the need for large current.

Because of its simplicity, and the less expensive parts, the use of air to control the circuits seems most logical.

Controls to be automated on the machine are those normally controlled by the operator when he is on board. Connecting the automatic controls to the direct drive controls (Figure 13) offers advantages of ease of operator control and simplified operation of the remote control devices. By remotely controlling the levers and pedals instead of just the function, the operator at the panel can operate those controls just as he would on board. Also, controlling the functions at the actual control linkage eliminates the need for lengthy, complicated mechanical systems.

A remote operator, located at a safe standoff distance, could have difficulty in controlling the depth of a cut the machine is taking. More positive control of the cut can be gained through complete automated control of the cutting tool by a laser (Figure 14) [13]. By having the cutting tool of the machine follow a laser, more accurate digging and final grading can be accomplished. This also speeds up the operation



Key: 1 - Forward - straight switch
2 - Forward right turn - right turn switch
3 - Forward left turn - left turn switch
4 - Transmitter unit
5 - Receiver unit
6 - Transmission lever
7 - Right clutch lever
8 - Left clutch lever
9 - Other commands

FIGURE 13: Example of Operation Controls Related to Controls On-Board Machine.

by allowing the operator to concentrate only on the movement of the machine in general. Not having to carefully control the control the earthmoving operation will enable more efficient operation.

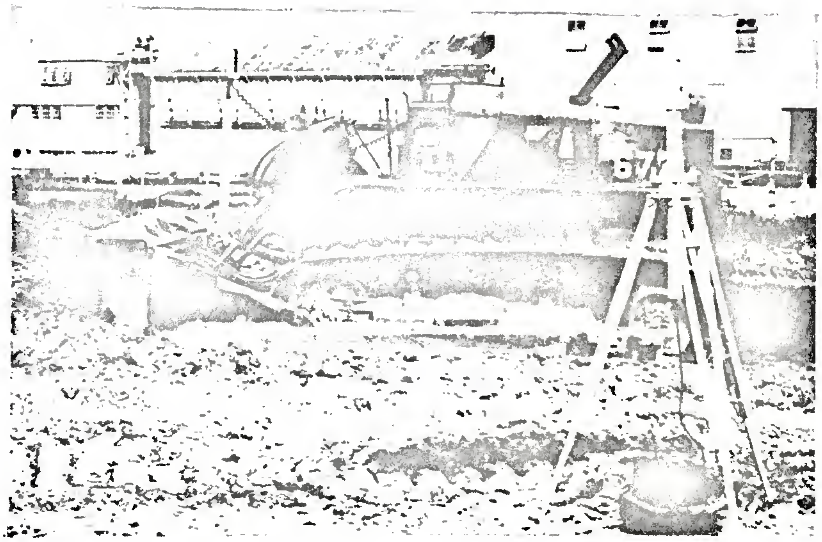


FIGURE 14: Bulldozer Being Guided by Laser.

Because the general remote control utilizes electromechanical valves to control the pressure in hydraulic or air hoses, difficulty occurs in making fine adjustments. Use of a laser trace would eliminate this. A laser can control the blade angle of a grader, for example, to within a degree [13].

The basic units of a laser system include the laser, the receiver and the control devices. The basic laser is a geodimeter modified to read lateral angle and converts the distance and angle coordinates into cartesian coordinates, using readily available integrated circuitry [13]. To keep the laser sweeping horizontally, a rotating prism is employed to redirect the beam within the horizontal plane. Also, by sweeping in this manner, the laser can do surveying work simultaneously [13].

Control of the blade or digging tool is through electro-mechanical valves of the type previously discussed. These valves are operated by the laser in the same manner that is realized through operation of the remote control panel. The only difference being that full automation of the digging is accomplished through use of the laser.

Proven feasible, remote control of the machinery used on the actual range would greatly increase the operator safety. Further, use of the laser would permit the operator a greater standoff distance since the digging and grading performed by the machine is being controlled by the laser.

C. Personal Contacts

The following individuals were contacted by project investigators during this reporting period:

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ANNEX A
SURVEY OF TWENTYNINE PALMS IMPACT RANGE

1. General Physical Description

This range covers an extensive desert area with a variety of terrain features. While the target zones are reasonably flat, the surrounding terrain is badly eroded, hilly in some places, and interrupted with arroyas and low, sheer banks. Lava flows have produced some extremely rugged formations in the northern section and a sizable lava lake and a dry lake bed are in the northeast corner (CHARLIE Area) of the range. Vegetation is limited to typical scrub and mesquite; almost nothing grows on the flat portions of the desert floor.

2. Range Areas

The range is subdivided into areas as shown in Figure A-1. The designations and descriptions of these areas follos:

X-RAY - This southernmost area (excluding the main base) is used for troop maneuvers and blind firing only. No impact of high explosive ordnance is permitted.

ALFA - This is primarily a maneuver area. Firing is permitted; however, all rounds fired from this area must impact into BRAVO I, BRAVO II, CHARLIE, DELTA, ECHO, or FOXTROT Areas.

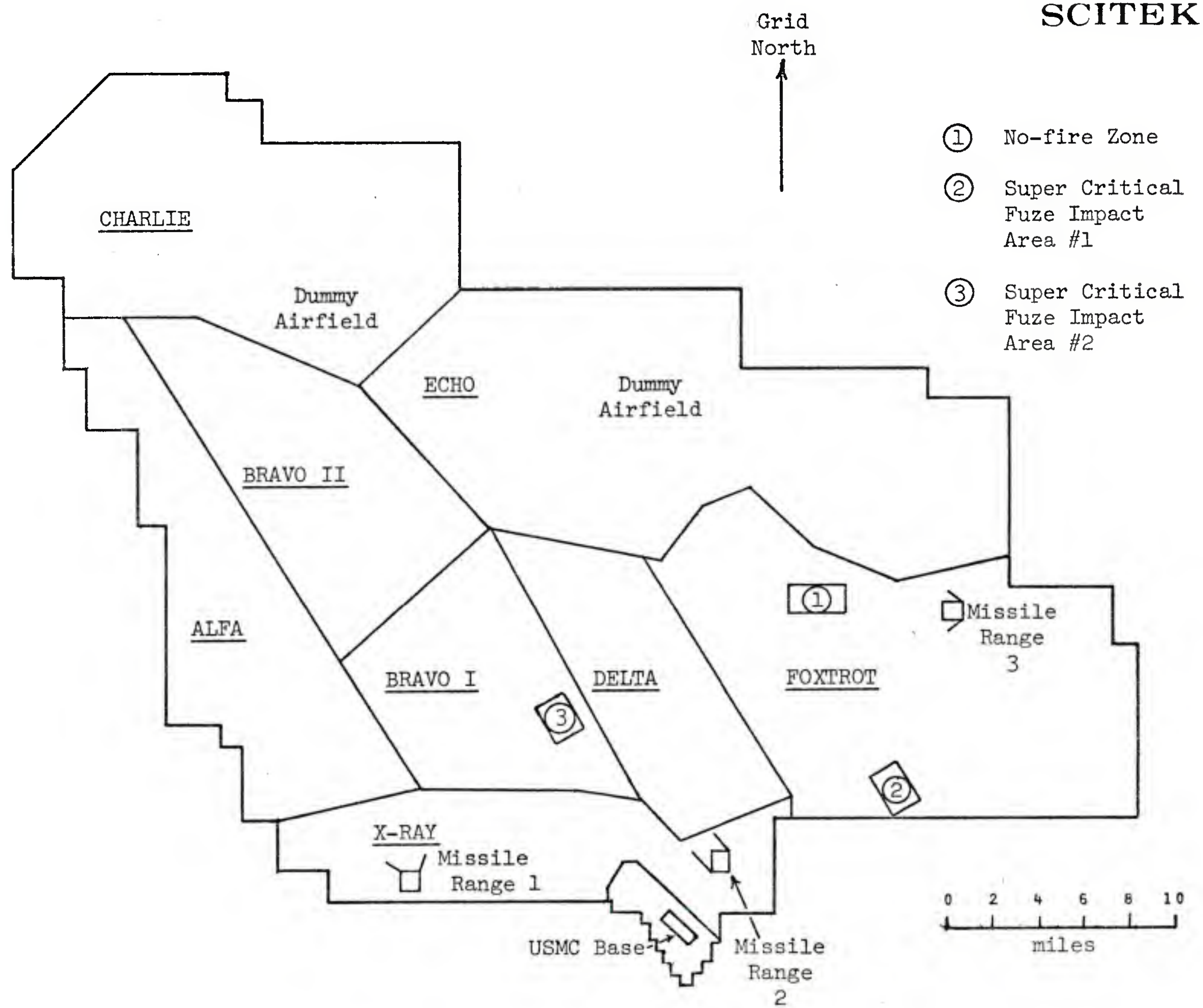

FIGURE A-1: Twentynine Palms Impact Range.

BRAVO I - This area is a firing and impact area for all conventional ground weapons. It is used for troop maneuver, but a dud ordnance hazard exists.

BRAVO II - This is a firing and impact area for all conventional ground weapons. It is used for troop maneuver, but personnel must be indoctrinated on the dud ordnance hazard.

CHARLIE - This area is used for firing and impact of all conventional weapons. It is also used as an impact area for aircraft ordnance. Troop maneuver is not normally permitted in the area.

DELTA - This is a firing and impact area for all conventional ground weapons and for impact of aircraft ordnance. There is a dud ordnance hazard and troop maneuver is infrequent in this area.

ECHO - This area is used for firing and impact for all conventional weapons and is an impact area for aircraft ordnance. Troop maneuver is not permitted here.

FOXTROT - This is a firing and impact area for all conventional ground weapons. The area is infrequently used for troop maneuver because of the dud ordnance hazard.

Super Critical Fuze Impact Areas #1 and #2 - These zones are set aside for the impact of ordnance with sensitive fuzes. Specific examples are: 106mm HEAT rounds, 90mm HEAT rounds, and 120mm HEAT rounds.

Missile Range #1 - This is the primary range for firing the HAWK missile and for conducting Redeye training exercises.

Missile Range #2 - This is the primary range for firing the Redeye missile. It is used an alternate range for HAWK missile firing and for Redeye tracking exercises.

Missile Range #3 - This is an alternate range for HAWK missile firing.

3. Summary

Project investigators traversed the range by jeep and observed conditions dictating that overland access to many of the range areas would be limited to all-terrain vehicles. The simulated airfields, such as was seen in CHARLIE Area, were strewn with debris from targets (aircraft, vehicles, and gunmounts) that had been placed there. Craters from large impacting ordnance were common; however, dud or inert ordnance was quite visible over much of the surface, which tended to be hard and baked by the desert climate.

ANNEX B
SURVEY OF CHOCOLATE MOUNTAIN IMPACT RANGE

1. General Physical Description

This impact range lies between the Salton Sea and the Chocolate Mountains in California. Although the mountains and their attendant slopes are formidable terrain features in this region, the impact area, in most cases, is confined to the flat desert along the western edge of the mountains. The surface of the range is more flat than was observed at Twenty-nine Palms and does not contain the discontinuities such as were caused by erosion on the Twentynine Palms range. The soil at the surface tends to be very fine silt but the underlying strata are baked hard and deep penetrations by impacting ordnance would be rare. The ground is covered by small rocks and pebbles over a majority of the surface and vegetation is very sparse and low.

2. Range Area

Vehicular targets are scattered throughout the range area. Some are lined along the slopes of the mountain range and at least one simulated "convoy" was seen in a gorge between slopes. In these target situations, several items of ordnance were observed on the adjacent hillsides; in most cases, the ordnance contamination is confined to the flat desert floor. As shown in Figure B-1, several observation posts are

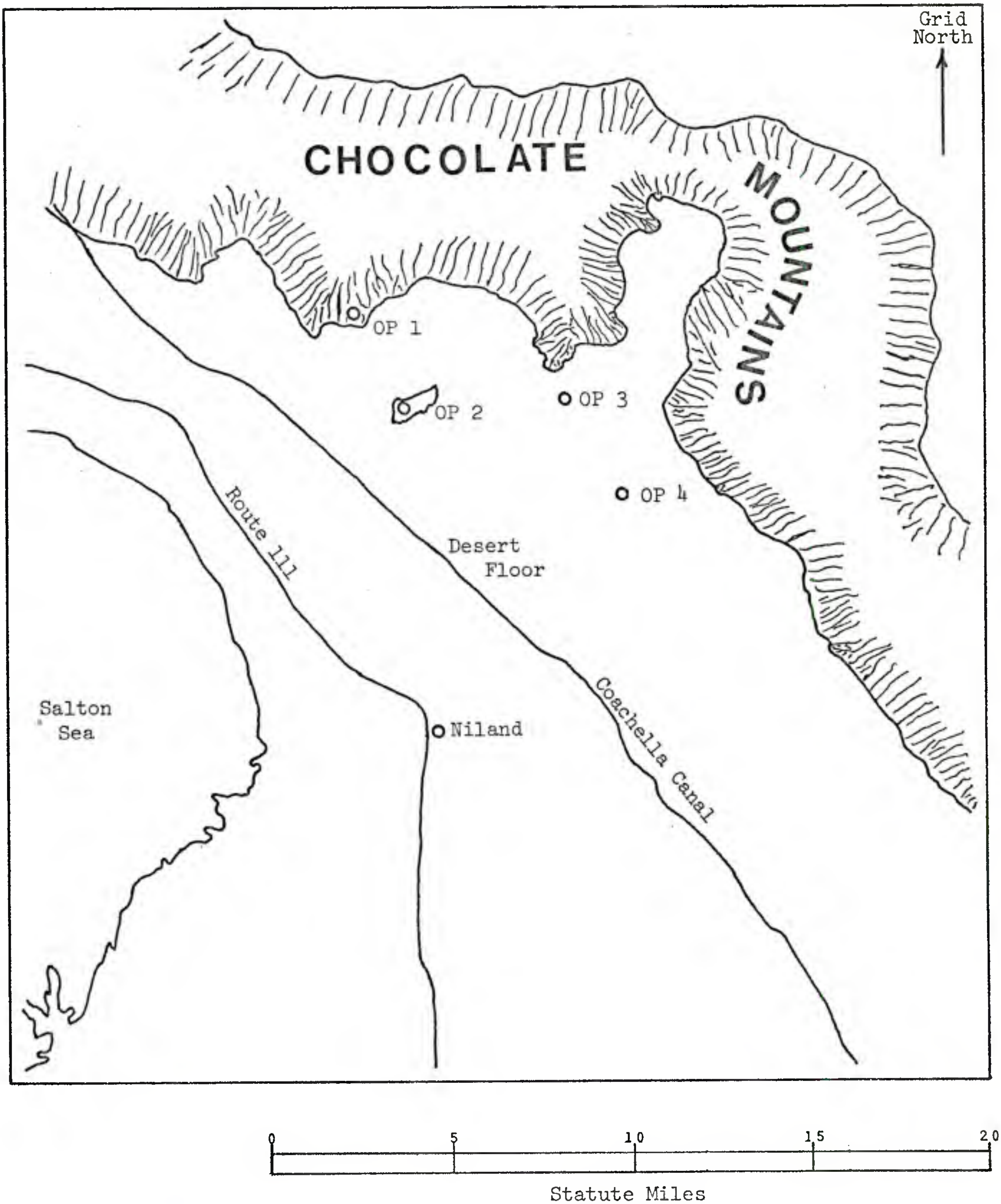

FIGURE B-1: Chocolate Mountains Impact Range.

positioned in the main impact area. These are placed on hills overlooking the desert and sandbagged bunkers have been erected on the points for protection of the observer.

3. Summary

The terrain and access roads were not as difficult to traverse as those experienced by the project investigators in their visit to Twentynine Palms. The target areas are on flat expanses of desert; a few exceptions do occur, where target vehicles have been placed in sheltered ravines or gorges. There were craters and dud rounds on the surrounding hills, but not in such quantity that they present unsurmountable clearance problems. Surface contamination in the target areas is extensive and the debris from the targets presented a situation similar to that seen at Twentynine Palms.